(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 December 2001 (06.12.2001)

PCT

(10) International Publication Number
WO 01/93488 A1

(51) International Patent Classification[7]: H04L 1/20, G10L 21/02

(21) International Application Number: PCT/EP00/04984

(22) International Filing Date: 29 May 2000 (29.05.2000)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: STEMERDINK, Jan [NL/NL]; Meijerink 8, NL-7101 VW Winterswijk (NL).

(74) Agents: VAN KAN, J., J., H.; Algemeen Octrooibureau, World Trade Center, Pastoor Petersstraat 160, NL-5612 LV Eindhoven et al. (NL).

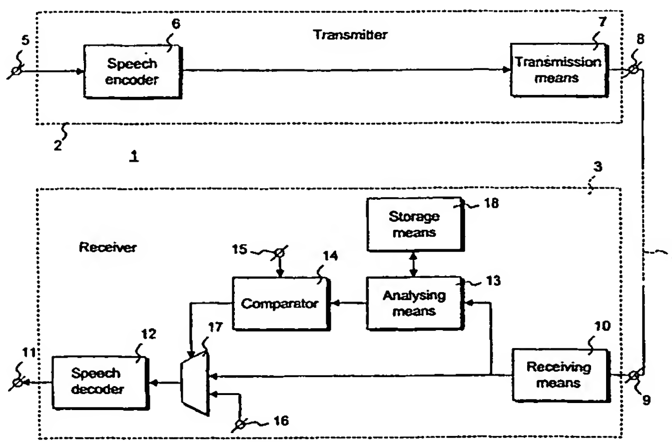
(81) Designated States *(national)*: AE, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ERROR DETECTION AND ERROR CONCEALMENT FOR ENCODED SPEECH DATA



(57) Abstract: For error detection in encoded speech communications, wherein a speech signal is encoded and transmitted in bit sequences (22), a received bit sequence is analysed as to its statistical properties (25). In an embodiment, wherein a received bit sequence is analysed as to its probability of occurrences in the encoded speech communications, a bit sequence is treated as an erroneous bit sequence if the probability of occurrence of this bit sequence is below of first threshold value (26). A plurality of subsequently received bit sequences may be analysed as to their probability of occurrence in the encoded speech communications. If the plurality of bit sequences comprises a number of bit sequences of which the probability of occurrence is below the first threshold value, this plurality of bit sequences is treated as comprising an error burst if this number exceeds a second threshold value (29). If an error burst has been determined, the plurality of received bit sequences may be replaced (31). The speech signal may be encoded following a Delta modulation technique, in particular Continuous Varying Slope Delta (CVSD) modulation.

WO 01/93488 A1

ERROR DETECTION AND ERROR CONCEALMENT FOR ENCODED SPEECH DATA

Field of the Invention

The present invention relates to speech communications and, in particular, to error detection and error correction in radio speech communications wherein a speech signal is digitally encoded and transmitted in bit sequences.

Background of the Invention

In radio communications, such as mobile or cordless radiotelephony, speech transmissions are likely to be impaired by interference from a plurality of RF sources or other sources producing RF interference. This interference often occurs in the shape of short error bursts, which are relatively short periods wherein the received signal contains virtually no information.

In digital communications systems, wherein a speech signal is encoded and transmitted in bit sequences, error bursts may produce random bit sequences. This may present itself to the listener as crackling noise or other artefacts in the decoded speech signal.

In various packet transmission techniques, for example, wherein speech bit sequences are transmitted in packets, comprising a header portion identifying a particular packet, the header is generally error protected. This enables a receiver to identify whether the header is corrupted by interference. If errors are detected in the header, the packet is considered to be lost and the received speech data are not further processed.

Forward error protection is an error protection technique by which error protection bits are added to the data bits at the transmitter side, such as parity bits or Cyclic Redundancy Check (CRC) bits. The data bits and the error protection bits together fulfil a certain mathematical rule that is known to both the transmitter and the receiver. If the received data and error protection bits do not fulfil this rule, the receiver knows that an error must have occurred. As will be appreciated by those

skilled in the art, by adding more error protection bits to the data, the probability of detecting and eventually correcting errors increases. Because of channel capacity considerations, in practice, the number of error correction bits, which can be added, is limited.

In a packet format of an emerging new radio communication standard for cordless radio communication called Bluetooth, voice data packets are transmitted in which only error protection bits are added to the header. However, if only the speech data are corrupted by interference and the header is not, the receiver will interpret this as a correctly received packet. The corrupted speech data are then decoded and passed to an output, such as a loudspeaker in a radiotelephone, for example. This results in an annoying crackling noise.

In a radiotelephone application, for example, a receiver can only take countermeasures against crackling noise if it has information on whether or not the received speech data have been corrupted by interference. However, applying forward error correction to the speech data, which may contain several bit sequences, may require in many cases a too large amount of error correction bits or may not be provided for in certain standardised communication systems.

Summary of the Invention

It is an object of the present invention to provide a method and arrangement for error detection in speech communications, in particular radio speech communications wherein a speech signal is encoded and transmitted in bit sequences, without adding error correction bits to the encoded and transmitted bit sequences.

It is in particular an object of the present invention is to provide a method of and an arrangement for the detection of error bursts in received speech data in a radio communications system wherein a speech signal is digitally encoded and transmitted in bit sequences.

These and other objects and advantages are achieved in accordance with the present invention in that a received bit sequence of encoded speech communications is analysed as to its statistical properties.

The invention is based on the insight that a digitally encoded speech signal is often not a pure random binary sequence, but rather comprises certain statistical properties. Accordingly, after encoding of a speech signal into bit sequences, it is to be

expected that not all of the theoretically available bit sequences will appear with equal probability, for example. By analysing, in accordance with the present invention, a received bit sequence as to its statistical properties associated with encoded speech communications, it can be determined with a certain likelihood whether the received bit sequence is an erroneous bit sequence as a result of interference at the transmission path from a transmitter to a receiver.

In accordance with the present invention, if the probability of occurrence of a bit sequence is below a first threshold value, this bit sequence is treated as an erroneous bit sequence.

It will be appreciated that the method according to the invention does not require the addition of bits or other data to the speech signal, neither before nor after the encoding thereof, such that the available transmission capacity of a communication channel is not impaired. Further, the method according to the invention can be applied with any new or existing speech communications system, provided that the encoded bit sequences exhibit a non-uniform statistical distribution, for example, such that not all of the bit sequences appear with like probability.

In packet transmission schemes, a plurality of encoded bit sequences are transmitted, generally representing a certain amount (time) of speech. The occurrence of error bursts by which a plurality of subsequent bit sequences are distorted may have a severe impact on the intelligibility of the speech communication.
Accordingly, in a further embodiment of the invention, wherein if the plurality of bit sequences comprises a number of bit sequences of which the probability of occurrence is below a first threshold value, the plurality of bit sequences is treated as comprising an error burst if the respective number exceeds a second threshold value.

The statistical properties of bit sequences in encoded speech communications can be empirically determined and stored during a training phase. This training phase may be conducted during the design phase, for example, and stored. It is preferred to store the results in storage means of a receiver, such that an instantaneous decision can be made as to the status of a received encoded bit sequence.

The statistical properties to be determined and stored may include, in accordance with the present invention, the probabilities of occurrence of bit sequences of encoded speech communications.

The statistical properties are advantageously stored in addressable storage means, wherein the bit sequences forming addresses pointing to their associated entries in the storage means. For example a table or matrix like storage means.

In accordance with the present invention, an error log-likelihood can be computed indicating an a posteriori probability or likelihood that a plurality of subsequently received encoded bit sequences comprise a burst error, by statistically processing the stored entries of received bit sequences.

In particular in the case of relatively long bit sequences, for processing economy, the invention provides that the statistical properties of sub-sequences of received bit sequences are determined, stored and processed.

For analysing the statistical properties of a received encoded bit sequence, in an embodiment of the invention, it is assumed that each bit sequence consists of independent sub-sequences. In another embodiment of the invention, it is assumed that the probability of a sub-sequence depends on its preceding sub-sequence, following a discrete-time Markov chain, for example.

Once an erroneous bit sequence has been determined, as a measure of error correction the received erroneous bit sequence is replaced by another bit sequence. If, however, an error burst has been detected the plurality of received bit sequences representing the speech signal in a packet, for example, are replaced.

Replacement of a plurality of bit sequences may include replacement by a plurality of bit sequences representing silence or replacement by a previous correctly received plurality of bit sequences of the same or ongoing speech communication.

It has been found that the method according to the invention provides excellent results if the speech signal is encoded following a Delta modulation technique, in particular Continuous Varying Slope Delta (CVSD) modulation, such as applied with the Bluetooth communications technology.

An introduction to the Bluetooth system can be found in "BLUETOOTH – The universal radio interface for *ad ho*c, wireless connectivity," by J.C. Haartsen, Ericsson Review No. 3, 1998.

The invention further provides a radio transceiver arrangement, comprising means for communicating speech signals arranged for operation in accordance with the method disclosed above. The transceiver arrangement may comprise a portable electronic appliance, for example.

The invention will now be described in more detail with reference to the enclosed drawing.

Brief Description of the Drawings

Figure 1 shows a simplified block diagram of a transmitter and receiver arranged for wireless telecommunications, incorporating the method according to the present invention.

Figure 2 shows a simplified flow chart diagram illustrating an embodiment of the method according to the present invention.

Detailed Description of the Embodiments

The invention will now be disclosed with reference to a block diagram of a general wireless radio transmitter and receiver arrangement. However, the teachings of the invention are likewise applicable to wired telecommunications or any other type of wireless radio communication.

Figure 1 shows an arrangement 1 for wireless radio transmission, comprising a transmitter 2 and a remote receiver 3. The transmitter 2 and receiver 3 communicate over an RF (Radio Frequency) transmission path 4, indicated by dashed lines.

At an input terminal 5 of the transmitter 2 a speech signal is applied, such as a speech signal from a microphone (not shown) of a radiotelephone device. Before transmission thereof, the speech signal is encoded into digital bit sequences by a speech encoder 6. The output of the speech encoder 6 is fed to transmission means 7 having an output terminal 8 for transmission to the receiver 3 via RF antenna means, for example.

The receiver 3 comprises receiving means 10 having an input terminal 9 for receiving RF signals, such as transmitted over the transmission path 4.

The output of the receiving means 10 is applied to statistical analysing means 13 for analysing a received bit sequence as to its statistical properties and switching means 17. In a preferred embodiment of the invention the analysing means 13 are arranged for computing an error log-likelihood of the received bit sequences.

In the embodiment shown, the output of the analysing means 13 connects to a comparator 14 for comparing the determined statistical properties of a received encoded bit sequence with a first threshold value or second threshold value in the case of a plurality of received bit sequences. These threshold values are applied at an input terminal 15 of the comparator means 14.

If it has been established that a bit sequence is correctly received, same will be switched through the switching means 17. However, if a bit sequence is in error, switching means 17 are operated by the comparator means 14 such that the erroneous bit sequence is replaced from a source and applied at an input terminal 16 of the switching means 17. In the case of an error burst, the plurality of bit sequences affected by the error burst is replaced, such as the whole content of speech information in a packet of a packet transmission system.

Eventually, the processed bit sequences are fed from the switching means 17 to a speech decoder 12 and provided as a reproduced speech signal at an output terminal 11 of the receiver 3, such as a loudspeaker of a radiotelephone.

Whenever strong interferences occur on the transmission path 4, one would like to take countermeasures to avoid annoying cracks in the reproduced speech signal, for example. A muting procedure may be included, which replaces the received corrupted data by a bit sequence or bit sequences representing silence. In the alternative, the corrupted encoded bit sequences may be replaced by previously correctly received encoded bit sequences of the speech communication and temporarily stored in storage means.

The effectiveness of such countermeasures depends highly on the availability of accurate information on the presence of interference. The analysing means 13 are arranged to provide this information based on the received bit sequence. It derives this information from the received bit sequence based on the a priori knowledge of (the statistical characteristics of) the transmitted encoded speech data and of the interference.

From decision theory, in particular from the theory of hypothesis testing, it is known that the optimum detection of errors can be based on the so-called likelihood ratio defined as:

$$L(y) = \frac{\Pr\{y \mid H_1\}}{\Pr\{y \mid H_0\}} \tag{1}$$

wherein: y = the received encoded bit sequence (the observation),

H_1 = the hypothesis that an error burst has occurred,

H_0 = the hypothesis that no error burst has occurred.

The likelihood ratio $L(y)$ of the actually received bit sequence is a so-called sufficient statistic: it contains all the information present in the received bit sequence y that can help to decide whether there is an error-burst in the signal or not.

$\Pr\{y \mid H_0\}$ is the (a priori) probability that the bit sequence y is received when there is no interference; and is equal to the probability that the speech encoder 6 generates a particular encoded bit sequence y.

$\Pr\{y \mid H_1\}$ is the (a priori) probability that the bit sequence y is received when interference is present.

An optimum detector can be implemented by computing the likelihood ratio and comparing it to a threshold ϑ_L. The decision rule for the detector could then be:

$$\text{decide}\begin{cases} D_1 & \text{(bit error burst)} \quad \text{if} \quad L(y) \geq \vartheta_L \\ D_0 & \text{(no bit error burst)} \quad \text{if} \quad L(y) < \vartheta_L \end{cases} \tag{2}$$

For practical reasons it is often preferred to work with the log-likelihood ratio $\Lambda(y) = \log_2 L(y)$ and to compare same to the corresponding threshold $\vartheta_\Lambda = \log_2 \vartheta_L$.

In the case of analysing means 13 implemented as an error-likelihood estimator, the operation thereof may be based on:

- statistical characteristics of the output of the speech encoder, i.e. the statistical characteristics of the transmitted data, as expressed in $\Pr\{y \mid H_0\}$

- the statistical characteristics of the received data, i.e. the speech encoder output with interference, as expressed in $\Pr\{y \mid H_1\}$.

The method is based on differences in statistical characteristics between the transmitted bit-stream and a bit-stream resulting from interference. It will be appreciated that a reliable error estimator can only be constructed when the statistics

of the transmitted data $\Pr\{y \mid H_0\}$ and the statistics of the data corrupted by interference $\Pr\{y \mid H_1\}$ show significant differences.

It is assumed that, whenever interference occurs, the received data will be completely random. This is, for example, a valid approach in speech communication following the Bluetooth standard, since a Bluetooth receiver includes a de-whitening filter, which causes any other information than the transmitted signal to be randomised. This causes a uniform distribution $\Pr\{y \mid H_1\}$ over all bit sequences y (during interference), which means that all realisations of y are equally probable.

Then, in order for the analysing means 13 to be able to discriminate between transmitted data and interference, the distribution $\Pr\{y \mid H_0\}$ must be skewed (non-uniform). This means that the speech encoder 6 has to generate different patterns with different probabilities.

In the case of Blue tooth, for example, the encoder operates in accordance with the so-called CVSD (Continuous Varying Slope Delta) modulation, which samples the speech signal at the rate of 64000 samples/second, whereas the input speech signal is offered to the encoder in 8000 samples/second. This 'oversampling' causes the speech encoder's output to have a very skewed distribution, which makes $\Pr\{y \mid H_0\}$ very non-uniform.

This distribution $\Pr\{y \mid H_0\}$ is computed by counting occurrences of values of sub-sequences in the output of the encoder, during a long training with a large variety of voice samples. The distribution $\Pr\{y \mid H_1\}$ of bit patterns during interference is assumed uniform (all received patterns are equally probable during interference).

The CVSD speech encoding and decoding are sequential processes. This means that the length of received bit sequences y is infinite or at least very large. Therefore it is impracticable to perform computations of probabilities $\Pr\{y \mid H_0\}$ and $\Pr\{y \mid H_1\}$, and of (log-) likelihood ratios over the full length of a bit sequence. Moreover, information on the presence of interference should be available immediately or shortly after the signal has been received.

Therefore, in such a case, the transmitted x and received y bit sequences will be split up into sub sequences or finite length vectors, and these vectors will be

split up into symbols (of 4 or 8 bits, for example):

$$x = (x_1, x_2, \ldots, x_M) \quad \text{and} \quad y = (y_1, y_2, \ldots, y_M) \tag{3}$$

wherein: x_i and y_i are $k-$bit symbols ($k = 4$ or 8, for example).

Next, for each received vector y of $N = k \times M$ bits the error burst likelihood is computed. Let $P_X(x) = \Pr\{X = x\}$ be the probability that the encoder generates vector x, for all 2^N possible combinations of N bits. Then it is found that:

$$\Pr\{y \mid \text{no bit error burst}\} = \Pr\{y \mid H_0\} = P_X(y) \tag{4}$$

The (assumed) uniform distribution of all received sequences of N bits during interference results in:

$$\Pr\{y \mid \text{bit error burst}\} = \Pr\{y \mid H_1\} = \left(\tfrac{1}{2}\right)^N = 2^{-N} \tag{5}$$

Now the simple expression for the error burst likelihood ratio is:

$$L(y) = \frac{2^{-N}}{P_X(y)} \tag{6}$$

The exact computation of $P_X(\cdot)$ and of $L(y)$ for any arbitrary sequence y is impracticable. Therefore, an approximation $\widetilde{P}_X(\cdot)$ of the real probability distribution $P_X(\cdot)$ will be used, which is sufficiently similar to the expected real distribution $P_X(\cdot)$ under most expected conditions. The approximation $\widetilde{P}_X(\cdot)$ should also be chosen such that the likelihood ratio $L(y)$ can be computed in a practical (not too complex) algorithm for any received vector y of substantial length, e.g. a packet of 240 bits like in Bluetooth. In practice this means that $\widetilde{P}_X(y)$ can be decomposed into elementary probabilities of the elements of the vector y.

Two examples will be considered here. First, the transmitted sequence x is assumed to be a vector whose elements consist of independent symbols, and second

the sequence x is assumed to be a vector whose elements are a discrete-time Markov chain.

In the case of independent identically distributed symbols, it is assumed that the transmitted sequence $x = (x_1, x_2, \ldots, x_M)$ consists of independent identically distributed (i.i.d.) symbols. , the elements of x are assumed to be independent and identically distributed (i.i.d.). Then the joint probability equals the product of the symbol probabilities:

$$\widetilde{P}_X(x) = \widetilde{p}(x_1) \cdot \widetilde{p}(x_2) \cdot \cdots \cdot \widetilde{p}(x_M) = \prod_{i=1}^{M} \widetilde{p}(x_i) \tag{7}$$

The distribution $\widetilde{p}(x_i)$ of the symbols x_i can be determined during training by counting the occurrences of all possible values at the output of the CVSD encoder over a long input voice (or noise) signal.

To this end, extraction means may be provided, which extract statistics from the speech bit sequences encoded by the speech encoder 6. From the extracted statistics, a log-likelihood table may be computed. The thus computed table is stored in storage means 18. For example such that the bit sequences or sub-sequences form addresses, which point to the corresponding entries in the storage means 18.

The storage means 18 are preferably arranged in the receiver 3, such to compute real time received erroneous bit sequences. It will be appreciated that a transmitter 2 and a receiver 3 may be integrated in a single transceiver arrangement, such as a radio base station and/or a portable or mobile telephone, for example.

Next the error-burst likelihood ratio becomes:

$$L(y) = \frac{2^{-k \cdot M}}{\prod_{i=1}^{M} \widetilde{p}(y_i)} = \prod_{i=1}^{M} \frac{2^{-k}}{\widetilde{p}(y_i)} \tag{8}$$

wherein: $N = k \cdot M$ is the length of the sequences in bits.

In certain cases, however, it is more convenient to construct a new test statistic, the log-likelihood ratio:

$$\Lambda(y) = \log_2 L(y) = \sum_{i=1}^{M} \left(-k - \log_2 \widetilde{p}(y_i)\right) = \sum_{i=1}^{M} \lambda(y_i) \tag{9}$$

wherein the values

$$\lambda(y_i) = -k - \log_2 \widetilde{p}(y_i) \tag{10}$$

are computed from the symbol statistics for each of the 2^k possible values of symbol y_i and stored in a table.

Upon reception of sequence $y = (y_1, y_2, \ldots, y_M)$ the receiver computes:

$$\Lambda(y) = \sum_{i=1}^{M} \lambda(y_i) \tag{11}$$

by simply adding the λ-values from the table at location y_i.

The decision rule for detection is then:

$$\text{decide} \begin{cases} D_1 & \text{(bit error burst)} \quad \text{if} \quad \Lambda(y) \geq \vartheta = \log_2 \vartheta_L \\ D_0 & \text{(no bit error burst)} \quad \text{if} \quad \Lambda(y) < \vartheta = \log_2 \vartheta_L \end{cases} \tag{12}$$

In the case of the Markov model, the probability distribution of a symbol x_i is assumed to depend only on the preceding symbol x_{i-1}:

$$\widetilde{P}_X(x) = \widetilde{p}(x_1) \cdot \widetilde{p}(x_2 \mid x_1) \cdot \widetilde{p}(x_3 \mid x_2) \cdots \widetilde{p}(x_M \mid x_{M-1}) = \widetilde{p}(x_1) \prod_{i=2}^{M} \widetilde{p}(x_i \mid x_{i-1}) \tag{13}$$

In this equation, $\widetilde{p}(x_i \mid x_{i-1})$ is the estimated transition probability from symbol x_{i-1} to symbol x_i. This is a finite-state discrete-time Markov model with 2^k states, where each symbol represents a state. The values of these transition probabilities can be determined during training by counting the occurrences of the transitions over a long input signal, for all possible values of x_{i-1} and x_i.

Now the error-burst likelihood ratio becomes:

$$L(y) = \frac{2^{-k \cdot M}}{\widetilde{p}(y_i) \prod_{i=2}^{M} \widetilde{p}(y_i \mid y_{i-1})} = \frac{2^{-k}}{\widetilde{p}(y_i)} \prod_{i=2}^{M} \frac{2^{-k}}{\widetilde{p}(y_i \mid y_{i-1})} \tag{14}$$

Again, the log-likelihood ratio is more practicable:

$$\Lambda(y) = \log_2 L(y) = -k \cdot M - \log_2 \widetilde{p}(y_1) - \sum_{i=2}^{M} \log_2 \widetilde{p}(y_i \mid y_{i-1}) \qquad (15)$$

or:

$$\Lambda(y) = -k - \log_2 \widetilde{p}(y_1) - \sum_{i=2}^{M} \left(-k - \log_2 \widetilde{p}(y_i \mid y_{i-1})\right) = \lambda_0(y_1) + \sum_{i=2}^{M} \lambda(y_{i-1}, y_i) \qquad (16)$$

For the computation of this test statistic, a table of 2^k values of $\lambda_0(y_1) = -k - \log_2 \widetilde{p}(y_1)$ is required, as well as 2^{2k} values of $\lambda(y_{i-1}, y_i) = -k - \log_2 \widetilde{p}(y_i \mid y_{i-1})$ for all 2^{2k} possible transitions (combinations of values of y_{i-1} and y_i).

Upon reception of sequence $y = (y_1, y_2, \ldots, y_M)$ the receiver computes:

$$\Lambda(y) = \lambda_0(y_1) + \sum_{i=2}^{M} \lambda(y_{i-1}, y_i) \qquad (17)$$

by simply adding the λ-values from the table at the address composed of symbol pair values (transitions) (y_{i-1}, y_i).

The discontinuity at the beginning of each vector can be removed by extending the current vector by a prefixed copy $y_0 = y'_M$ of the last symbol y'_M from the previous vector. Then the computation will be:

$$\Lambda(y) = \sum_{i=1}^{M} \lambda(y_{i-1}, y_i) \qquad (18)$$

Upon reception of sequence $y = (y_1, y_2, \ldots, y_M)$ the analysing means 13, if implemented as an error likelihood estimator compute the error log-likelihood $\Lambda(y)$.

In the case of independent symbols this computation is described by:

$$\Lambda(y) = \sum_{i=1}^{M} \lambda(y_i) \tag{19}$$

and if a Markov model is used for the symbol statistics:

$$\Lambda(y) = \lambda_0(y_1) + \sum_{i=2}^{M} \lambda(y_{i-1}, y_i) \tag{20}$$

The values $\lambda(y_i)$, $\lambda_0(y_1)$ and $\lambda(y_{i-1}, y_i)$ are fetched from a table. This table contains the entries for all 2^k possible values of $k-$bit symbol y_i, or for all 2^{2k} possible values of symbol pairs (y_{i-1}, y_i).

Although the invention has been disclosed above with reference to analysing means 13 designed as an error likelihood estimator, it will be appreciated that other types of statistical analysing means may be used within the context of the present invention.

Figure 2 shows a simplified flow chart diagram of an embodiment of the method according to the invention, disclosed above, in the case of a communications system wherein encoded speech data are transmitted in packets, such as in the Bluetooth system.

A speech signal input, indicated by block 20, is encoded by encoding means, such as encoding means operating following the CVSD modulation technique, which results in bit sequences, block 21.

A plurality of bit sequences representing a certain period of encoded speech are transmitted in packets, block 22. In practice, the transmitted packets will become more or less distorted by interference at the transmission part, block 23. Accordingly, the transmitted data packets will be received as packets containing distorted speech encoded bit sequences, block 24.

Next, in accordance with the present patent application, the received distorted bit sequences contained in a packet are analysed as to their statistical properties. For example as to the probability of occurrence of each particular bit

sequence in encoded speech communication, block 25. This statistical analysis may be performed using the results of a training phase, stored in a memory of the receiver.

If it has been determined that the statistical properties, such as the probability of occurrence, of a particular bit sequence are below a first threshold, block 26 'yes', this bit sequence will be counted as an erroneous bit sequence, block 27. Otherwise, block 26 'no', if the particular bit sequence is not the last bit sequence of the packet, block 28 'no', the next bit sequence of the packet will be analysed, block 25.

If the last bit sequence of a received packet has been analysed, block 28 'yes', it is determined whether the number of erroneous bit sequences are above a second threshold, block 29. In the affirmative, block 29 'yes', one may conclude that the received data packet has been distorted by an error burst, block 30, such that processing of the respective packet will result in crackling noise or otherwise will impair the intelligibility of the speech, such that further processing of the packet should be cancelled. The received bit sequences may all be replaced by bit sequences representing silence or otherwise. The thus replaced bit sequences are decoded, block 32 and provided as output speech, including silence.

If the analysing step does not reveal an error burst, the received bit sequences of a data packet are decoded, block 32 and provided as output speech, block 33.

Those skilled in the art will appreciate that in the method shown in Figure 2, if the occurrence of an error burst is not likely, the individual bit sequences having statistical properties below the first threshold may be individually replaced. For example from an interpolation of bit sequences adjacent to the erroneous bit sequence, as indicated in broken lines by block 34. As will be appreciated by those skilled in the art, further amendments and additions can be made to the above-disclosed embodiment, without departing from the spirit and scope of the present invention.

Claims

1. A method of error detection in encoded speech communications, wherein a speech signal is encoded and transmitted in bit sequences, characterised in that a received bit sequence is analysed as to its statistical properties.

2. A method according to claim 1, wherein a received bit sequence is analysed as to its probability of occurrence in said encoded speech communications.

3. A method according to claim 2, wherein if the probability of occurrence of a bit sequence is below a first threshold value , said bit sequence is treated as an erroneous bit sequence.

4. A method according to claim 1, wherein a plurality of subsequently received bit sequences are analysed as to their probability of occurrence in said encoded speech communications.

5. A method according to claim 4, wherein if said plurality of bit sequences comprises a number of bit sequences of which the probability of occurrence is below a first threshold value, said plurality of bit sequences is treated as comprising an error burst if said number exceeds a second threshold value .

6. A method according to any of the previous claims, wherein the statistical properties of bit sequences in said encoded speech communications are empirically determined and stored during a training phase.

7. A method according to claim 6, wherein the probabilities of occurrence of bit sequences are determined and stored.

8. A method according to claim 6 or 7, wherein said statistical properties are stored in addressable storage means, and said bit sequences forming addresses pointing to their associated entries in said storage means.

9. A method according to claim 8, wherein an error log-likelihood is computed indicating an a posteriori probability or likelihood that a plurality of subsequently received bit sequences comprise an error burst by statistically processing said stored entries of received bit sequences.

10. A method according to claim 6, 7, 8 or 9, wherein the statistical properties of sub-sequences of received bit sequences are determined, stored and processed.

11. A method according to claim 10, wherein for analysing said statistical properties of a received bit sequence, it is assumed that each bit sequence consists of independent sub-sequences.

12. A method according to claim 10, wherein for analysing said statistical properties of a received bit sequence, it is assumed that the probability of a sub-sequence depends on its preceding sub-sequence.

13. A method according to claim 12, wherein said sub-sequences are assumed to be a discrete-time Markov chain.

14. A method according to any of the previous claims, wherein a received erroneous bit sequence is replaced by another bit sequence.

15. A method according to claim 14 dependent on claim 5, wherein if an error burst has been determined, said plurality of received bit sequences is replaced.

16. A method according to claim 15, wherein said plurality of bit sequences is replaced by a plurality of bit sequences representing silence.

17. A method according to any of the previous claims, wherein said speech signal is encoded following a Delta modulation technique, in particular Continuous Varying Slope Delta (CVSD) modulation.

18. A method according to claim 17, wherein said speech signal is encoded and transmitted in accordance with a standardised communications technology called Bluetooth.

19. A radio transceiver arrangement, comprising means for communicating speech signals, said means being arranged for operation in accordance with the method of any of the previous claims.

20. A radio transceiver arrangement according to claim 19, wherein said transceiver arrangement is a portable electronic appliance.

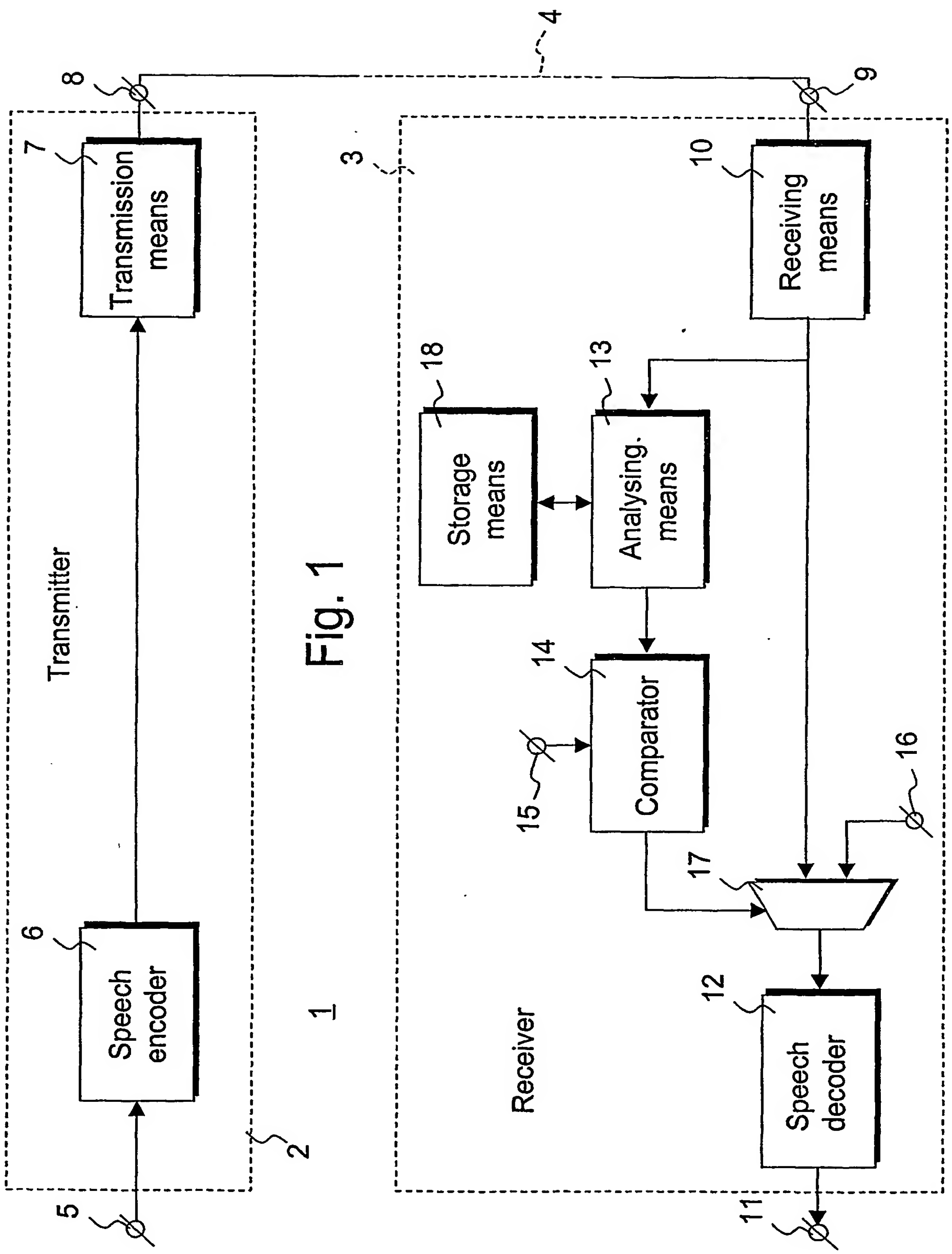

Transmitter
Speech encoder
Transmission means
Receiver
Receiving means
Storage means
Analysing. means
Comparator
Speech decoder
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Fig. 1

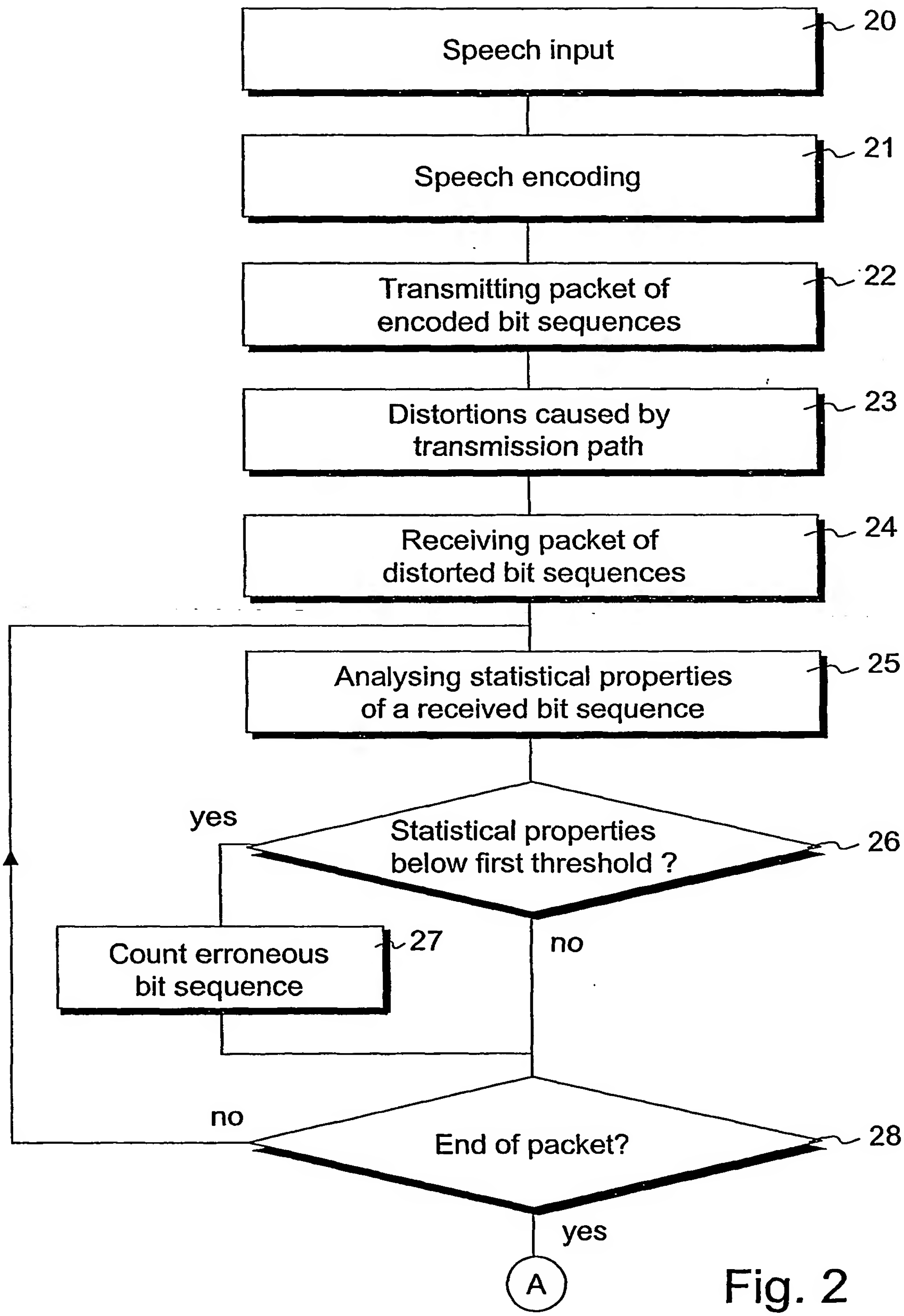

Speech input
20
Speech encoding
21
Transmitting packet of encoded bit sequences
22
Distortions caused by transmission path
23
Receiving packet of distorted bit sequences
24
Analysing statistical properties of a received bit sequence
25
Statistical properties below first threshold ?
26
yes
no
Count erroneous bit sequence
27
End of packet?
28
no
yes
A

Fig. 2

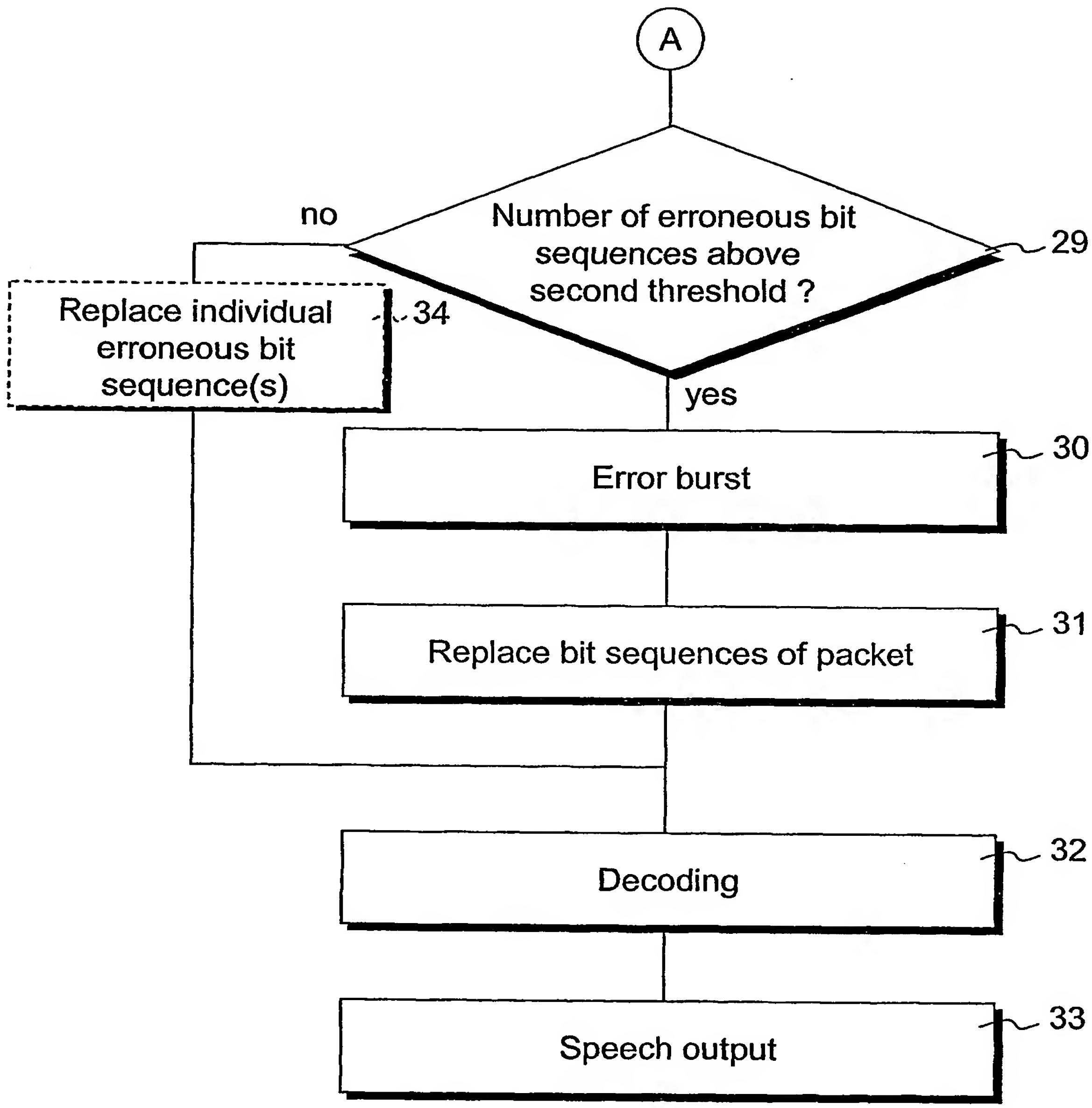

A
Number of erroneous bit sequences above second threshold ?
29
no
Replace individual erroneous bit sequence(s)
34
yes
Error burst
30
Replace bit sequences of packet
31
Decoding
32
Speech output
33

Fig. 2 (cont.)

INTERNATIONAL SEARCH REPORT

Inte[illegible] ial Application No
PC[illegible]/[illegible]P 00/04984

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/20 G10L21/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N G10L H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PROAKIS JOHN G. : "DIGITAL COMMUNICATIONS, 3RD. EDITION" 1995 , MCGRAW-HILL , NEW YORK, NY, USA XP002156591 page 483, line 35 -page 485, paragraph 1	1-4, 17-20
X	US 5 416 788 A (CAREY MICHAEL J) 16 May 1995 (1995-05-16) abstract column 1, line 6 -column 3, line 34 column 4, line 22 -column 7, line 36	1-4, 17-20
A		5-7,10

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2001	25/01/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Koukourlis, S

INTERNATIONAL SEARCH REPORT

Inter al Application No
PCT/EP 00/04984

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 598 506 A (WIGREN KARL T ET AL) 28 January 1997 (1997-01-28) abstract page 1, line 26 - line 67 column 3, line 19 - line 58 column 4, line 66 -column 5, line 10	1,17-20
A	claims	14-16
X	US 5 936 972 A (MEIDAN REUVEN ET AL) 10 August 1999 (1999-08-10) abstract column 2, line 7 -column 4, line 38	1,17-20
A		14-16
X	US 5 502 713 A (LAGERQVIST TOMAS ET AL) 26 March 1996 (1996-03-26) abstract column 1, line 12 -column 3, line 3 column 4, line 13 -column 5, line 20	1,17-20
X	WO 95 03674 A (BRITISH TELECOMM ;MURPHY ANGELA RUTH (GB); GUNBY STEPHEN RICHARD () 2 February 1995 (1995-02-02) abstract page 1, line 32 -page 3, line 18	1,17-20
A		14-16
X	STEELE R ET AL: "Detection and selective smoothing of transmission errors in linear PCM" BELL SYSTEM TECHNICAL JOURNAL, vol. 56, no. 3, March 1977 (1977-03), pages 399-409, XP000978493 New York, USA ISSN: 0005-8580 abstract page 400, paragraph 3 -page 401, paragraph 1	1,17-20
A	US 5 790 595 A (BENTHIN MARCUS ET AL) 4 August 1998 (1998-08-04) the whole document	6-10
A	ALBRECHT M ET AL: "IP Services over Bluetooth: leading the way'to a new mobility" PROCEEDINGS 24TH CONFERENCE ON LOCAL COMPUTER NETWORKS, 18 - 20 October 1999, XP002130784 Los Alamitos, CA, USA page 3, left-hand column	17-20

-/--

INTERNATIONAL SEARCH REPORT

Inte   ıal Application No
PCı/ɛP 00/04984

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	MAH R S H: "Data screening" FOUNDATIONS OF COMPUTER AIDED PROCESS OPERATIONS. PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE, PARK CITY, UT, USA, 5 - 10 July 1987, pages 67-94, XP000978490 Amsterdam, Netherlands, Elsevier, Netherlands ISBN: 0-444-98925-0 abstract page 73, paragraph 4 -page 82, paragraph 1	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

ɪrmation on patent family members

Intern al Application No
PCT/EP 00/04984

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5416788 A	16-05-1995	AT 158681 T	15-10-1997
		DE 69222413 D	30-10-1997
		DE 69222413 T	19-03-1998
		DK 575422 T	27-04-1998
		EP 0575422 A	29-12-1993
		ES 2109346 T	16-01-1998
		WO 9216065 A	17-09-1992
		JP 6505374 T	16-06-1994
		SG 52316 A	28-09-1998
US 5598506 A	28-01-1997	SE 501340 C	23-01-1995
		AU 670514 B	18-07-1996
		AU 7011494 A	03-01-1995
		AU 670698 B	25-07-1996
		AU 7011594 A	03-01-1995
		AU 670699 B	25-07-1996
		AU 7011694 A	03-01-1995
		CA 2140363 A	22-12-1994
		CA 2140364 A	22-12-1994
		CA 2140365 A	22-12-1994
		CN 1110486 A	18-10-1995
		CN 1110883 A	25-10-1995
		CN 1110884 A	25-10-1995
		DE 69416493 D	25-03-1999
		DE 69416493 T	24-06-1999
		DE 69421500 D	09-12-1999
		DE 69421500 T	13-07-2000
		DE 69421501 D	09-12-1999
		DE 69421501 T	06-07-2000
		DK 655159 T	20-09-1999
		DK 655160 T	03-01-2000
		DK 655161 T	03-01-2000
		EP 0655159 A	31-05-1995
		EP 0655160 A	31-05-1995
		EP 0655161 A	31-05-1995
		ES 2129646 T	16-06-1999
		ES 2141236 T	16-03-2000
		ES 2141326 T	16-03-2000
		FI 950590 A	10-02-1995
		FI 950591 A	10-02-1995
		FI 950592 A	10-02-1995
		GR 3029729 T	30-06-1999
		GR 3031751 T	29-02-2000
		GR 3031787 T	29-02-2000
		JP 8500233 T	09-01-1996
		JP 8500234 T	09-01-1996
		JP 8500235 T	09-01-1996
		KR 220381 B	15-09-1999
		KR 220380 B	15-09-1999
		KR 220376 B	15-09-1999
		MX 9404250 A	31-01-1995
		MX 9404251 A	31-01-1995
		MX 9404252 A	31-01-1995
		NZ 267733 A	27-08-1996
		NZ 267734 A	25-06-1996
		NZ 267735 A	25-06-1996
		RU 2120667 C	20-10-1998
		RU 2120141 C	10-10-1998

INTERNATIONAL SEARCH REPORT

nation on patent family members

Inten ıal Application No
PCT/EP 00/04984

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5598506	A		RU	2120668 C	20-10-1998
			SE	9302025 A	12-12-1994
US 5936972	A	10-08-1999	CN	1208998 A	24-02-1999
			FR	2765754 A	08-01-1999
			GB	2328846 A	03-03-1999
			JP	11234143 A	27-08-1999
US 5502713	A	26-03-1996	AU	678667 B	05-06-1997
			AU	1251895 A	27-06-1995
			CA	2154253 A	15-06-1995
			CN	1119058 A	20-03-1996
			EP	0682831 A	22-11-1995
			FI	953707 A	03-08-1995
			JP	8508866 T	17-09-1996
			RU	2130693 C	20-05-1999
			WO	9516315 A	15-06-1995
			SG	49995 A	15-06-1998
WO 9503674	A	02-02-1995	AU	686198 B	05-02-1998
			AU	7192294 A	20-02-1995
			CN	1127578 A	24-07-1996
			DE	69413695 D	05-11-1998
			DE	69413695 T	18-03-1999
			EP	0710422 A	08-05-1996
			JP	9503890 T	15-04-1997
			NZ	268644 A	24-02-1997
			SG	47699 A	17-04-1998
			US	5745169 A	28-04-1998
US 5790595	A	04-08-1998	DE	4431237 A	07-03-1996
			EP	0700183 A	06-03-1996
			JP	8163185 A	21-06-1996